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Numerical Modeling of Wave Response in Hawaiian Harbors

by Lori L. Hadley and Edward F. Thompson

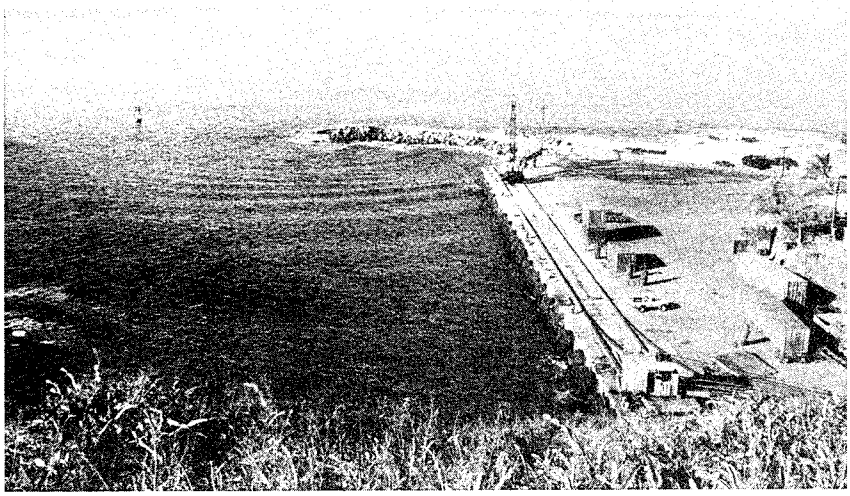

Figure 1. Kaumalapau Harbor, viewed from the east

Introduction

Harbor wave response is the change in interior wave conditions due to the interaction between incident waves and harbor structures and geometry. High wave activity inside a harbor can have destructive effects on moored and docking vessels as well as harbor facilities, and should be avoided or minimized whenever possible. Wave modeling is a critical ingredient in most harbor studies. Final designs are generally based on scaled physical model tests in which representative waves are mechanically generated and the response of a miniature harbor is measured. Numerical modeling usually provides a quicker, lower cost option which can be preferred for preliminary investigations of processes and design alternatives and for reinvestigation of well-documented harbors.

Harbor wave response modeling is an important part of Corps studies in which new harbors are being planned or existing harbors modified. The Corps numerical model HARBD calculates wave heights throughout a harbor, including both bottom friction and variable wave reflection from harbor structures (Chen and Houston 1987). Originally designed to evaluate harbor oscillations (low-frequency waves with periods greater than 20 sec), HARBD has been modified to include the shorter periods of wind waves and swell. A new effort in the Coastal Research Program will eventually upgrade this technology. The harbor itself is represented within the model by a grid of triangular elements. The ratio of local wave height to incident wave height is calculated at every node, or intersection, between elements. These values, known as wave "amplification" factors, can be output individually at every node or as averaged values taken over small selected regions (basins). Both forms of output provide a means of estimating areas of high and low wave activity within the harbor. The objectives of this article are to review two recent HARBD numerical model studies in the Hawaiian Islands and to illustrate present Corps modeling technology.

Wind Waves and Swell - Kaumalapau Harbor

The recent study of Kaumalapau Harbor illustrates the use of HARBD in the estimation of wind waves and swell within a harbor. Kaumalapau Harbor is a small harbor located along the southwest coast of the Hawaiian island of Lanai (Figure 1). It is the island's primary commercial port. Constructed in the late 1920's by the Dole Company, Kaumalapau Harbor is protected from the open ocean by a single rubble-mound breakwater which extends south from the northern corner of the harbor entrance. Over the years, this breakwater, particularly the seaward end, has suffered repeated damage due to hurricanes and winter storms. The most recent damage was caused by Hurricane Iniki in September 1992, followed by severe storms in February 1993, which left the most seaward 75 ft of the breakwater reduced to a submerged mound. The harbor is presently being transferred from private to state ownership.

Concern about difficult wave conditions prompted the State of Hawaii to seek the help of the U.S. Army Engineer Division, Pacific Ocean (POD) in evaluating the current extent of the harbor's protection as well as possible methods of improving that protection. At the request of POD, the U.S. Army Engineer Waterways Experiment Station's Coastal Engineering Research Center (CERC) assisted in the study with numerical and physical modeling and field wave gauging.

During the initial stage, HARBD results were used to aid in the placement of wave gauges within the harbor. Once the gauges were in place and functioning, the numerical study proceeded to test the effects of proposed harbor modifications on the wave climate. The main objective at this stage was to identify the most promising alternatives and limit the number of physical model tests.

To ensure complete representation of incident wave conditions, a wide range of incident wave periods and approach directions was tested. For each condition, comprehensive nodal output as well as averaged output at several locations along the main wharf were

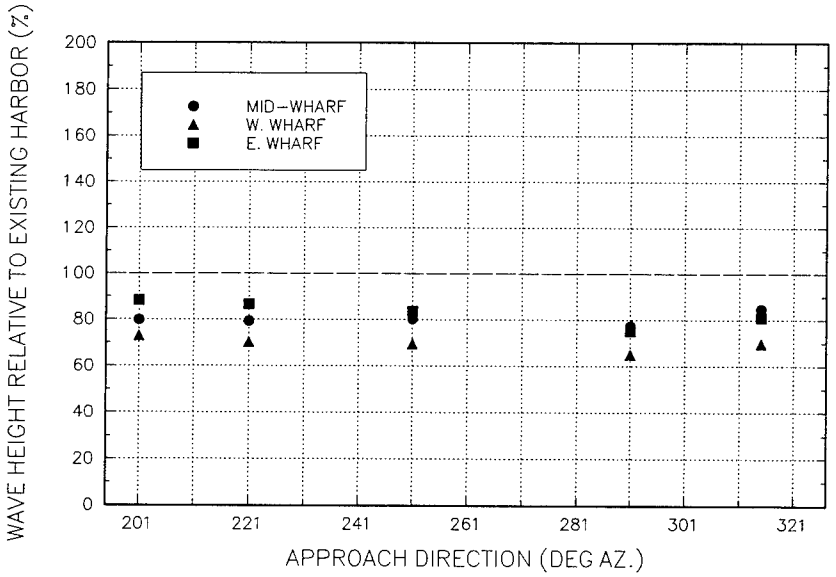

Figure 2. Evaluation of dogleg breakwater extension, T_p = 16 sec, Kaumalapau Harbor

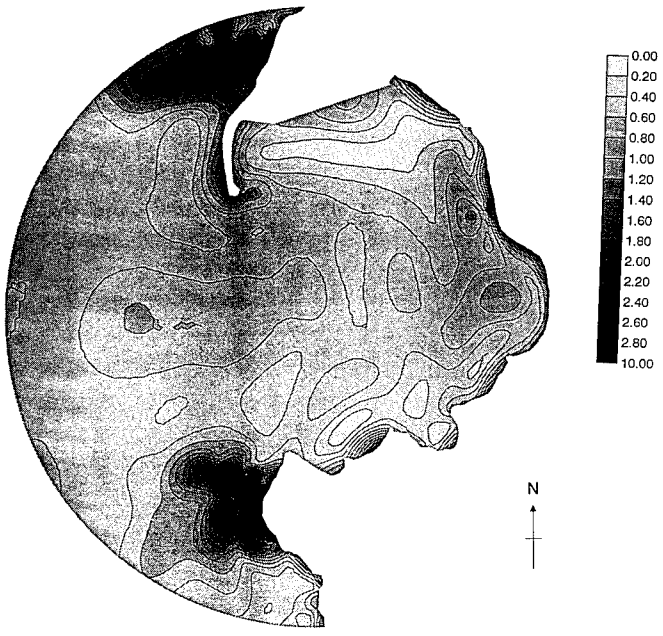

Figure 3. Amplification factor contours for existing Kaumalapau Harbor

obtained. This was done first for the existing layout of the harbor and then for a variety of alterative plans, including a straight breakwater extension, an extension set at an angle to the existing breakwater (dogleg extension), and a separate breakwater addition extending northwest from the southern corner of the harbor entrance. Basin results for each were plotted to show the ratio of amplification factor of the alternative plan to amplification factor of the existing plan versus the direction of wave approach, shown in Figure 2 for one alternative. The nodal results, on the other hand, were viewed as amplification factor contour plots of the entire harbor, produced using CERC's visualization software ACE/vis (Turner and Baptista 1993). Figure 3 shows results for the existing harbor excited by a 16-sec wave approaching directly into the harbor entrance. Results of these tests are being used to direct and focus the physical modeling stages of the Kaumalapau Harbor study.

Harbor Oscillations Maalaea Harbor

A second recent harbor study similarly centered on harbor wave response, but with emphasis on harbor oscillations. Maalaea Harbor, a small boat harbor located on the southwest coast of the Hawaiian island of Maui, has experienced problems caused by wave energy in the harbor. Therefore, modifications are being considered.

As with Kaumalapau Harbor, Maalaea Harbor was modeled for a wide range of incident wave conditions. Because it was suspected that Maalaea's problem stemmed in part from resonant response to longer period wave energy, a significant portion of the periods tested were longer than 20 sec, ranging from 20 to 200 sec. By plotting the full range of frequencies against resulting amplification factors, peaks indicating strong resonant response (modes of oscillation) were identified at various points in the harbor. Figure 4 shows the resonant peaks for both the existing harbor and an alternative called Plan 6, obtained for a basin at the northwest harbor corner near the present boat ramp. Nodal output for each period marking a resonance peak was also plotted to analyze the full extent of the harbor's response. An example is given in Figure 5 for the existing harbor. Areas of high amplification (dark regions at the west, center, and east parts of the harbor) are maxima in the resonant standing wave. Areas of low amplification

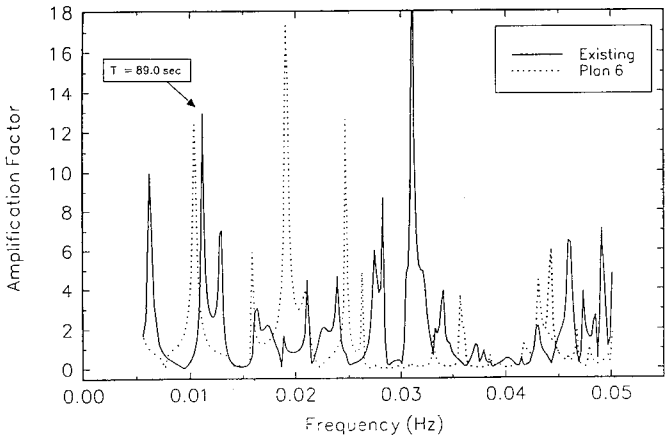

Figure 4. Amplification factors at northwest corner of Maalaea Harbor

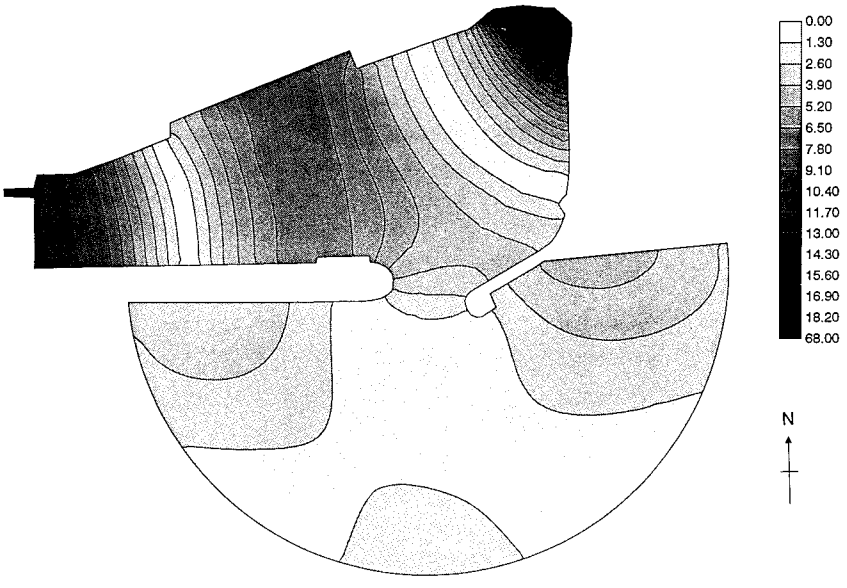

Figure 5. Amplification factor contours for resonant peak at 89.0-sec period (noted in Figure 5)

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(light regions offset from the center of the harbor) are minima. Although vertical motion is small at the minima, oscillating velocities are at a maximum. The resonant amplifications shown here are exaggerated since no bottom friction was included in the model runs. However, they give useful information about the impact of harbor modifications on oscillation strengths, periods, and patterns. Economic and time constraints have precluded physical modeling of Maalaea Harbor.

Summary

Numerical modeling of wave response plays an important role in harbor studies conducted by the Corps. Models such as HARBD provide valuable information about wave characteristics within a harbor. This information, in turn, provides guidance in the selection and modification of harbor designs. Final designs are generally validated and optimized with physical models. Kaumalapau Harbor and Maalaea Harbor are two examples of how the Corps has effectively applied its numerical harbor wave response modeling capabilities.

References

Chen, H. S., and Houston, J. R. (1987). "Calculation of water oscillation in coastal harbors: HARBS and HARBD user's manual," Instruction Report CERC-87-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Turner, P. J., and Baptista, A. M. (1993). "ACE/vis user's manual," Center for Coastal and Land-Margin Research, Oregon Graduate Institute of Science and Technology, Beaverton, OR.

Ms. Lori Hadley *earned a B.S. degree in physics from Southwest Texas State University and a B.S. in Ocean Engineering from Texas A&M University. Since joining the Research Division of CERC in 1992, she has worked predominately in areas of numerical harbor wave response modeling and ocean water level prediction.*

Dr. Edward F. Thompson *is a senior research hydraulic engineer in the Research Division of CERC. Since reporting to CERC in 1970, he has engaged in a wide range of research activities related to coastal waves, water levels, and meteorology. His degrees include a B.S. from the California Institute of Technology, an M.S. from the University of California at Berkeley, and a D.Sc. from George Washington University.*

Beachfill and Risk Assessment

A new course, Beachfill Design and Risk Assessment, is being developed within the U.S. Army Corps of Engineers PROSPECT training program. This course is being developed as the result of a recently conducted Competence 2000 survey of Corps of Engineers coastal specialists. The survey was conducted in cooperation with the Office of Personnel Management in response to a Chief of Engineers initiative (CERCular Vol. CERC-92-4, December 1992). A course registration survey will be conducted by the Corps' Huntsville Division in the January-March 1995 time frame. Corps of Engineers personnel should contact their training office for registration information. Other interested engineers and scientists should contact Mr. John Buckley, U.S. Army Engineer Division, Huntsville, at (205) 722-5898.

60th Meeting of the Coastal Engineering Research Board

The 60th meeting of the Coastal Engineering Research Board (CERB) was held on 8-10 November 1994, in Vicksburg, Mississippi. The CERB is Congressionally mandated to advise the Chief of Engineers on all matters related to coastal engineering. The Board meets twice a year in different geographical areas to obtain a better understanding of problems in the areas.

The Board is comprised of seven members. The President of the Board is MG Stanley G. Genega, Director of Civil Works. The other three military members are BG Ralph V. Locurcio, Commander, South Atlantic Division; BG Milton Hunter, Commander, North Atlantic Division; and BG Henry S. Miller, Jr., Commander, Pacific Ocean Division. The three civilian members are Dr. Paul D. Komar, Oregon State University; Dr. Robert G. Dean, University of Florida; and Dr. Edward K. Noda, Edward K. Noda and Associates, Inc., Honolulu, HI. The Commander of the U.S. Army Engineer Waterways Experiment Station acts as the Executive Secretary of the CERB and is responsible for all administrative functions of the Board.

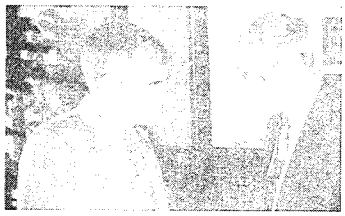
The theme of this meeting was "Coastal Research and Development." Speakers were from Headquarters, U.S. Army Corps of Engineers, U.S. Army Engineer Waterways Experiment Station (WES), and WES's Coastal Engineering Research Center (CERC). Presentations included an update of the Chief's Initiatives; the History of CERC/CERB, CERC Today, and Coastal Engineering in the Future; CERC Programs, Coastal Research and Development, Coastal Inlets Research Program, Coastal Field Data Collection Program, Monitoring Completed Coastal Projects (MCCP), DUCK94 and SANDYDUCK, Military Coastal Work, Dredging Research Program, Dredging Operations and Environmental Research, Coastal Environmentally Related Work, Numerical Modeling, Army Civil Works Mission Support; Scanning Hydrographic Operational Airborne Lidar Survey, and Summary and Future Directions.

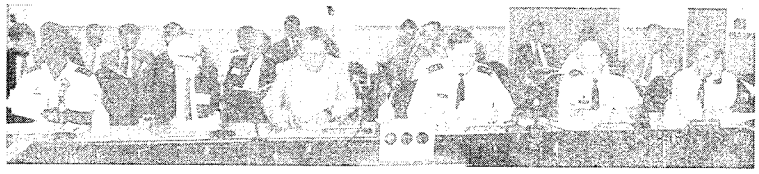
The dinner guest speaker was Mr. Terrence Winschel, Historian from the Vicksburg National Military Park.

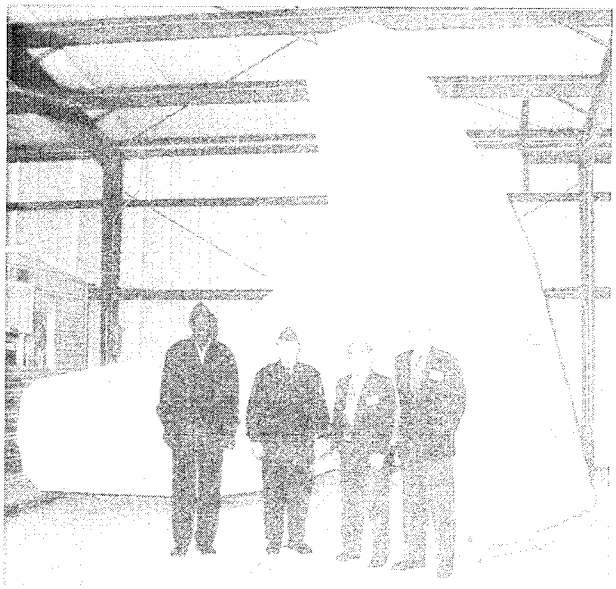
On the facilities tours, the Board was able to see firsthand the model work done at CERC. Models and demonstrations shown in the Jay V. Hall Building included the 42-ton dolos mock-up, the island tsunami model study, the general CORE-LOC design tests, and the Los Angeles-Long Beach model study. Demonstrations in the Prototype Measurement and Analysis Building included the automated real-time tidal elevation system, the Colorado River MCCP Project, and the underwater inspection of structures. Stability with waves and currents was shown in the L-shaped wave flume. The Kaumalapau Harbor Model Study, the Kodiak stability study, and the Camp Ellis Beach Saco Bay model study were shown in the R. Y. Hudson Building, and the Rochester Harbor model study was observed in Building 3275.

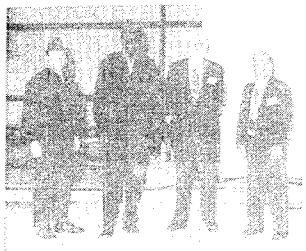
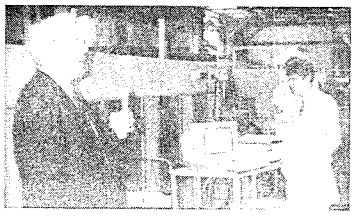
Proceedings of the meeting will be available. Point of contact is Ms. Sharon L. Hanks, WES, CERC, (601) 634-2004.

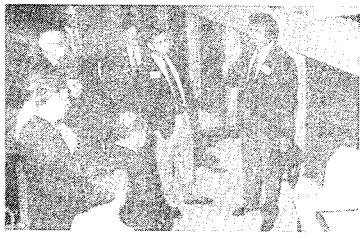
The next meeting of the CERB is scheduled for 9-11 May 1995 in Galveston, TX, with the theme "Coastal Zone Management."

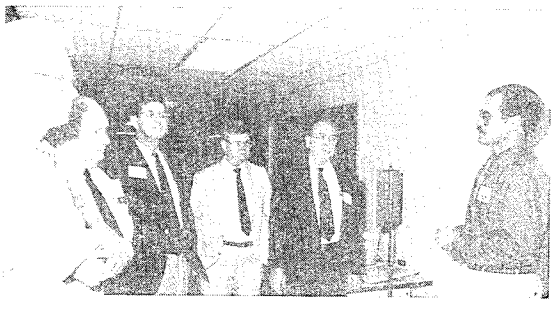
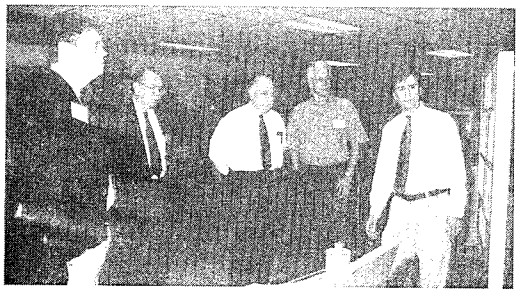





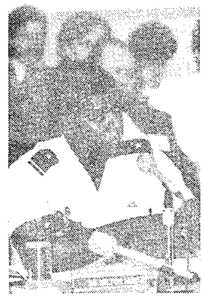


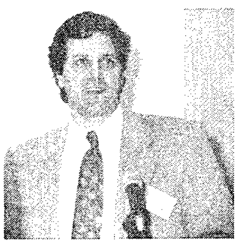







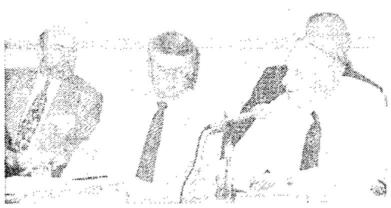








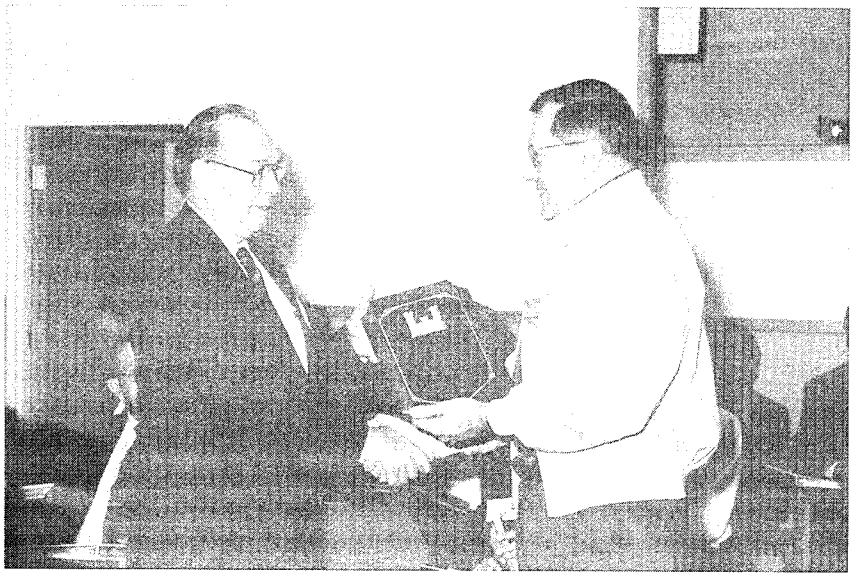


Mr. CERB Receives Plaque from Director of Civil Works

Mr. John G. Housley, recently retired from Headquarters, U.S. Army Corps of Engineers, is shown at left receiving a plaque from Major General Stanley G. Genega, Director of Civil Works and President of the Coastal Engineering Research Board (CERB), at the last meeting of the CERB held in Vicksburg, Mississippi, as a small token of appreciation for dedication and service to the Board. John has been a true friend of the CERB. Since CERC and CERB were established in 1963, he only missed one meeting, which was designated for Board members only. John certainly holds the record for attendance, and we don't believe anyone will ever match or better it.

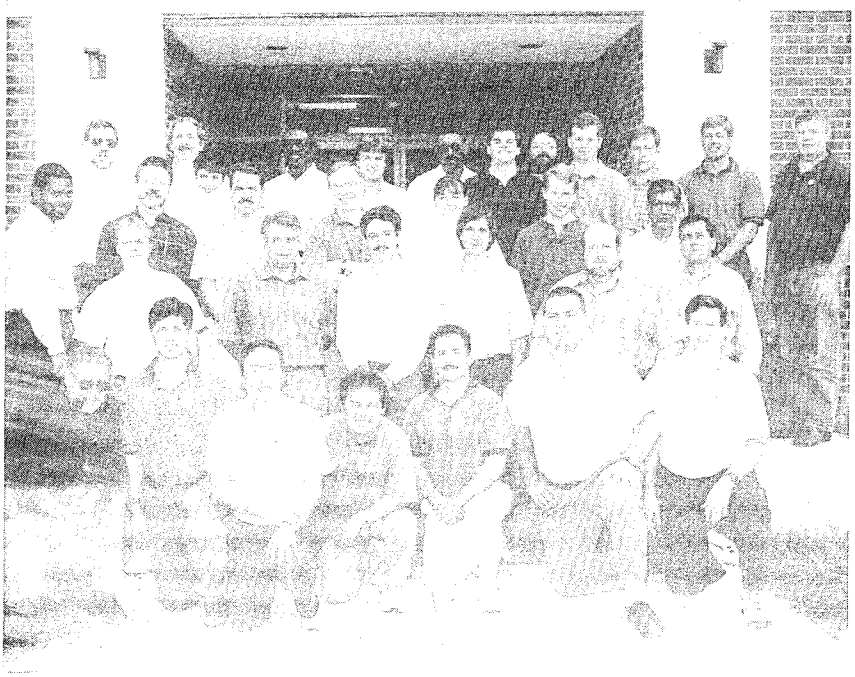
We hope to see John at future CERB meetings as a non-Corps participant.

NOTE: Major General Genega's luggage with his uniform was lost on his flight to Jackson.



Coastal Engineering Course

The Coastal Engineering I PROSPECT course was conducted at the U.S Army Engineer Waterways Experiment Station on 17-21 October. There were 32 attendees from Corps of Engineers offices, the U.S. Coast Guard, and state and local agencies. Coastal Engineering I emphasizes coastal processes including waves and longshore and cross-shore sediment motion. Coastal Engineering I and a companion course, Coastal Engineering II, which emphasizes coastal structures, are scheduled to be offered again in October 1995. POC for information on coastal engineering courses is Dr. Fred E. Camfield, (601) 634-2012, FAX (601) 634-3433, Internet: camfield@coafs1.wes.army.ml



Publications of Interest

The following publications are available from the sources indicated. They are not available from CERC.

Shoreline Management Guidebook, Volume I: Shoreline Administrator's Manual, Report No. 93-104B, 1994, 141 pages, loose leaf, $5; and *Volume II: Shoreline Master Program Handbook*, Report No.93-104C, 1994, 626 pages, loose leaf, $25. Specific to Washington State, but of possible interest to other jurisdictions. Volumes I and II can be ordered as a set with cover and spine inserts for $30. Order from Publications Office, Washington State Department of Ecology, PO Box 47600, Olympia, WA 98504-7600, telephone (206) 407-7472.

Long Island Coastal Conference: Scenario Planning & the Future of Long Island's Coastline and Near Coastal Environments, NYSGI-W-93-001, 1993, 136 pages, $10. Copies available from New York Sea Grant Institute, 115 Nassau Hall, SUNY at Stony Brook, Stony Brook, NY 11794-5001.

State of the Cape, 1994: Progress Toward Preservation, 260 pages, $11.40. Copies available from Association for the Preservation of Cape Cod, Box 636, Orleans, MA 02653.

Over the Wedge: Where Fresh and Salt Water Meet, WHOI-G-93-002, 11-by-14-inch black and white poster, free (supplies are limited). Available from WHOI Sea Grant Program, Woods Hole Oceanographic Institution, Woods Hole, MA 02543.

Wetlands - Guide to Science, Law, and Technology, 1994, 439 pages, $64. Copies available from Noyes Publications, 120 Mill Road, Park Ridge, New Jersey 07656, telephone (201) 391-8484, FAX (201) 391-6833.

Water Log, a quarterly publication reporting on legal issues affecting the Mississippi-Alabama coastal area, free. Copies available from Mississippi-Alabama Sea Grant Legal Program, University of Mississippi Law Center, University, MS 38677.

Developing a Volunteer Program for Environmental Education of the Public, 1993, 61 pages. Available from WSU Beach Watcher Program, Admiralty Head Lighthouse, P.O. Box 5000, Coupeville, WA 98239, telephone (206) 679-7391.

Coastal Vegetated Buffer Policies

A copy of the Rhode Island Coastal Zone Management Program's coastal vegetated buffer policies is available on E-mail from Alan Desbonnet, Coastal Resources Center, University of Rhode Island at aland@gsosun1.gso.uri.edu. This is about an 11-page printout. It covers setbacks, definition of buffer zones, findings, policies, standards, buffer management and maintenance requirements, guidelines for preparing an application, management options within buffer zones, and appropriate techniques for managing vegetation. While the particular policies apply to the state of Rhode Island, they will be of interest to other jurisdictions formulating policies.

Calendar of Coastal Events of Interest

Mar 29 - Apr 1, 1995	Gulf of Mexico Symposium, Corpus Christi, Texas POC: (800) 699-4853
Apr 3 - 7, 1995	Corps of Engineers National Interagency Workshop on Wetlands, Clarion Hotel, New Orleans, Louisiana POC: (601) 634-2569/4217 FAX (601) 634-3664
Apr 3 - 7, 1995	Marine & Estuarine Shallow Water Conference, Holiday Inn-Diplomat on the Boardwalk, Atlantic City, NJ POC: Ralph Spagnolo or Edward Ambrogio (215) 597-3642, FAX (215) 597-7906 or -1850 E-mail: spagnolo.ralph@epamail.epa.gov or ambrogio.edward@epamail.epa.gov
Apr 3 - 7, 1995	European Geophysical Society XX General Assembly, Hamburg, Germany POC: E-mail: EGS95@LINAX1.MPAE.GWDG.DE
Apr 11 - 14, 1995	National Hurricane Conference, Trump Taj Mahal, Atlantic City, NJ POC: David Tait, (904) 561-1163, FAX (904) 561-1172
May 1 - 4, 1995	Offshore Technology Conference, Houston, Texas POC: FAX 214-952-9435
May 24, 1995	Annual Dredging Seminar, Minneapolis, Minnesota
May 25 - 26, 1995	Western Dredging Association, Annual Meeting, Minneapolis, Minnesota
Aug 5 - 12, 1995	Int'l Assoc. for the Physical Sciences of the Oceans, General Assembly, Hilton Hawaiian Village, Honolulu POC: Internet: iapso@oceans.org
Jul 17 - 22, 1995	Coastal Zone '95, Tampa, Florida POC: Dr. Billy Edge, 409-847-8712, FAX 409-845-6156
Sep 4 - 9, 1995	Coastal Dynamics '95, Gdansk, Poland email: cdsec@hapcio.ibwpan.gda.pl FAX: (+4858) 524211
Sep 6 - 8, 1995	Coastal '95, Cancun, Mexico email: cmi@ib.rl.ac.uk
Sep 18 - 20, 1995	Remote Sensing for Marine and Coastal Environments, Seattle, Washington POC: FAX (313) 994-5123, Internet: wallman@vaxb.erim.org or rrogers@erim.org
Oct 18 - 21, 1995	7th Canadian Coastal Conference, Bedford Institute of Oceanography, Dartmouth, Nova Scotia POC: FAX (902) 426-4104, Internet: solomon@agc.bio.ns.ca
Nov 14 - 17, 1995	14th World Dredging Congress, Amsterdam, The Netherlands

Coastal Erosion Hazards

The Riegle Community Development and Regulatory Improvement Act of 1994 (PL 103-325, September 1994) includes numerous changes in the National Flood Insurance Program under title V of the Act. These include a requirement on coastal erosion hazards. The act directs FEMA to study communities subject to coastal erosion and assess costs and benefits of mapping, regulating, and insuring them. The study will determine the effect of such regulation and insurance on property values, tax revenues, employment, economic development, and the need for future federal and state disaster assistance. Five million dollars is authorized for mapping erosion hazards in a representative sample of communities.

COASTGIS NET

Darius Bartlett, University College, Cork, Ireland, has established a COASTGIS list that is maintained for people interested in using GIS for coastal zone science and/or management. There are presently some 250 subscribers. The list address is COASTGIS@IRLEARN.UCD.IE. Subscription requests should be sent to LISTSERV@IRLEARN.UCD.IE.